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PROGRAMMED INSTRUCTION IN WATER POLLUTION CONTROL. UNIT IV. WASTEWATER TREATMENT

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THE UNIVERSITY OF MICHIGAN

DEPARTMENT OF ENVIRONMENTAL HEALTH

PROGRAMMED INSTRUCTION IN

WATER POLLUTION CONTROL

UNIT IV WASTEWATER TREATMENT

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SCHOOL OF PUBLIC HEALTH

March 22, 1968

UNIT IV

PRINCIPLES OF

WASTEWATER TREATMENT

Details of illustrations in this document may be better studied on microfiche.

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March 27, 1968

This booklet was developed to teach some of the basic principles of wastewater treatment. After studying this booklet, the student or trainee should be in a better position to handle problems that come up in the treatment of wastewater.

Programmed learning methods are used in this booklet because they are designed to help people learn new material by themselves, with little or no help from a teacher.

IF YOU HAVE NOT USED PROGRAMMED INSTRUCTION BOOKS BEFORE, please start by reading the section, "What is Programmed Learning?" in Appendix A at the end of the booklet.

PART I

INTRODUCTION

WHAT IS POLLUTION?

1. Man's progress has brought with it more and more uses for water. For most of these uses, the quality of the water is important. But what has man done to preserve the quality of natural waters, so that they can satisfy his present and future needs? Obviously, not enough.

Even when men still lived in caves, streams contained some impurities, such as dead leaves and suspended soil. But these small amounts of impurities did not interfere with man's use of the water.

As time went on, the number of people increased, and industries sprang up. More impurities were poured into the streams.

As impurities build up, the quality of water in a stream falls until it becomes so low that the water has to be treated before it can be used. Then we say that the stream is polluted. Pollution is a relative word, depending on how we intend to use the water.

Wastewater is treated to reduce its polluting effects before it is discharged into a stream. The extent of treatment depends upon the degree of pollution and the intended use of the water in the stream. The treatment may use mechanical, chemical and biological methods.

This program will help you to understand the nature of wastewater, and some of the methods now used to treat it.

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1.1 Water is said to be polluted whenever its uses are limited by the impurities it contains.

a. A clear, sparkling stream can easily be changed to cloudy, foul-smelling, useless water, if raw _____ or untreated industrial _____ are discharged into it.

sewage wastes

b. In addition to making streams unsightly and smelly, untreated wastes can _____ fish and can make water unfit for humans to _____.

kill

use, or drink

1.2 Materials that cause pollution are called pollutants.

a. Pollutants discharged into a stream or other receiving water _____ the quality of the water receiving them.

lower, or decrease

b. A certain amount of pollutant causes less decrease in quality when it is discharged into a (☐ large / ☐ small) stream.

large

c. Water containing small concentrations of pollutants may still be acceptable, if the pollutants do not interfere with the intended _____ of the water.

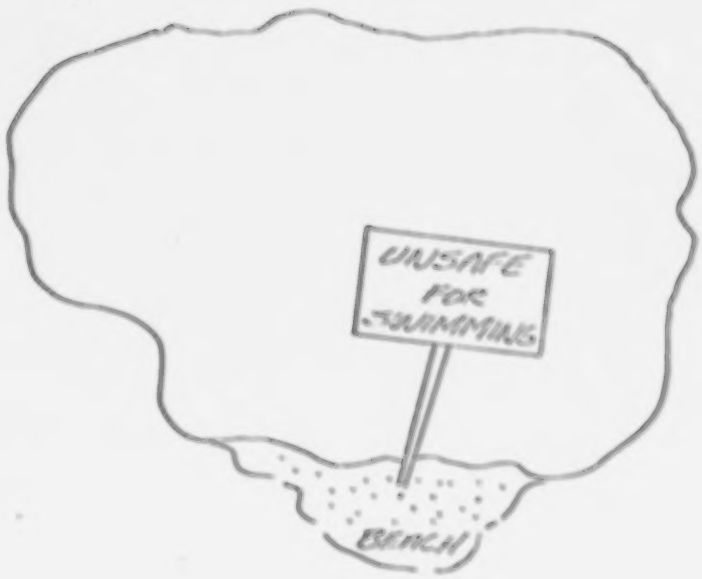
use

d. A stream containing pollutants may have a quality high enough for irrigation purposes, and may still be too _____ to be used as a drinking water supply.

polluted

e. Look at these pictures:

1.



2.

both pictures

Polluted water is shown in (☐ picture 1 / ☐ picture 2 / ☐ both pictures).

1.3 Our present pollution problems are mostly man-made. Some pollutants come from other sources, but the greatest quantities of pollutants, and the greatest concentrations, result from human activities.

a. Jed Clumpett's shack pours pollutants into Crud Creek all year round. In the spring, Crud Creek floods. The (☐ quantity / ☐ concentration) of pollutants in the creek is lower in spring.

concentration

b. When Jed's friend Zack comes to visit, with his 13 children, both the total _____ and the _____ of the pollutants in the creek increase.

quantity

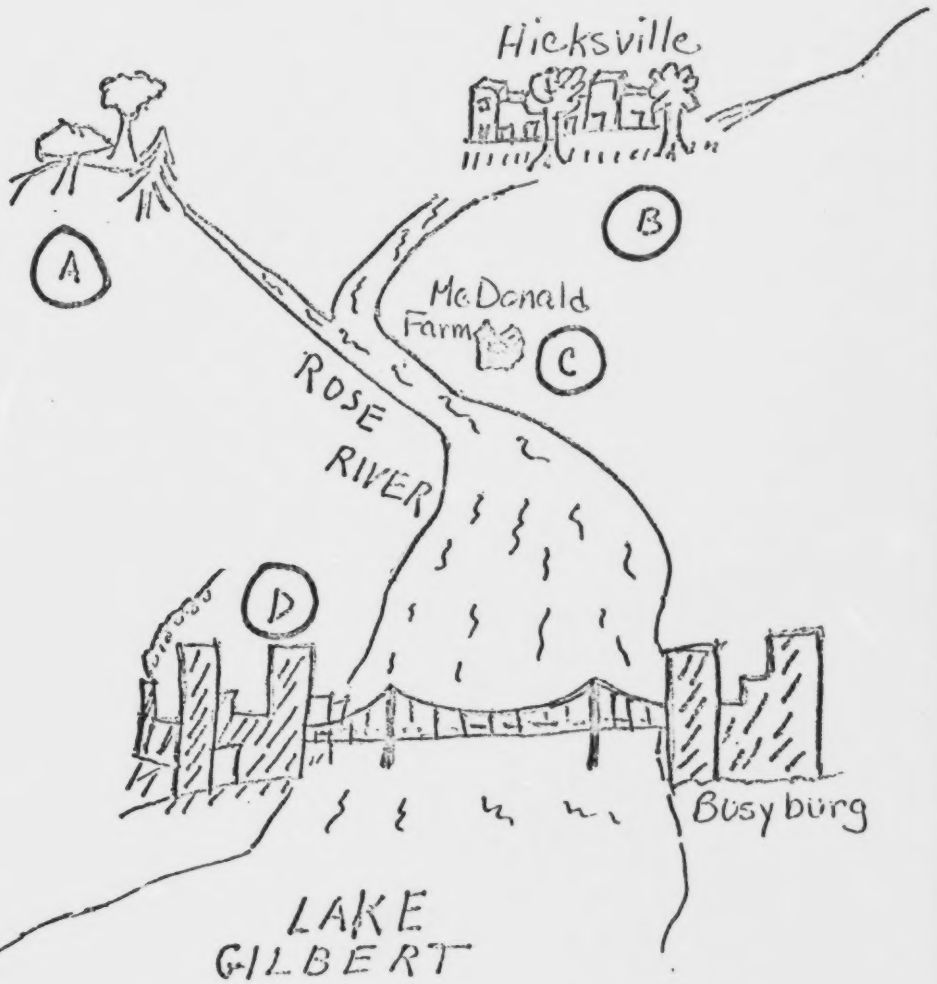
concentration

c. If Zack visits in the springtime, the _____ of pollutants is still greater than it was when Jed was alone in the winter, but the _____ of pollutants in the creek may be lower than in the winter.

quantity

concentration

d. From the picture below, pick the proper letter to show which source of pollutants causes the greatest amount of contamination of the lake. List the other sources in order, below the highest one.



D Highest: _____

B _____

C _____

A Lowest: _____

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1.4 As a stream flows along, it slowly purifies itself, because of the action of air and bacteria, or other microorganisms.

a. Natural self-purification can bring water quality up to an acceptable value, if the amount of pollutant added at any one point is _____.

low

b. The supply of air in the water, the temperature, and many other conditions have an effect on how fast a stream can _____ itself.

purify, or clean

c. Addition of pollutants at points close to one another may not allow enough _____ for the stream to purify itself.

time, or distance

d. Human activities can easily discharge so much pollutants into a stream that self-purification is not able to prevent _____ of the stream.

pollution

2. Sources of Pollution.

2.1 There are many kinds of pollutants:

Domestic wastewater comes from household activities.
Commercial wastewater comes from stores and restaurants.
Industrial wastewater comes from manufacturing and processing plants.

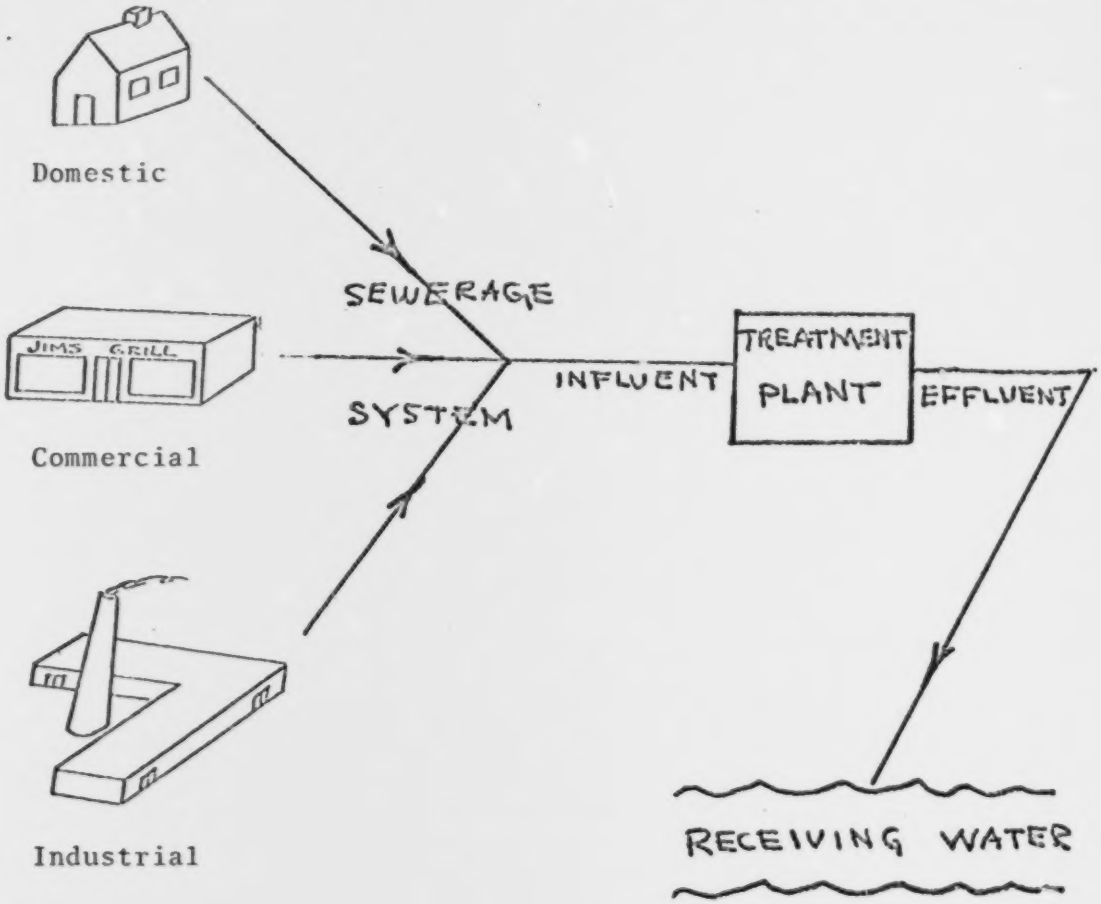
a. Wastewaters from domestic, commercial, and industrial sources (☐ all / ☐ do not) contain the same amounts and types of pollutants.

do not

b. Wastewater treatment methods (☐ may / ☐ do not) depend on the source of the wastewater.

may

2.2 The three types of wastewater may flow through the same pipes or sewers, or they may be collected separately.



a. The picture shows wastewater from all three sources flowing through a common _____ system to a _____ plant.

sewerage

treatment

b. The wastewater from the sewerage system makes up the influent that (☐ enters / ☐ leaves) the treatment plant.

enters

effluent

c. The wastewater discharged into the receiving water is the _____ from the plant.

effluent

d. There should be a relatively low concentration of pollutants in the treatment plant (☐ influent / ☐ effluent).

domestic
commercial
industrial

e. The composition of wastewater depends on how much of it comes from _____ sources, and how much from _____ sources or _____ sources.

domestic

f. Wastewater from different locations has a similar composition if it comes mostly from (☐ domestic / ☐ commercial / ☐ industrial) sources.

industrial

g. The treatment plant in a farming community handles practically no _____ wastewater.

2.3 The composition of the wastewater collected from a community changes from time to time.

a. The flow of <u>domestic</u> wastewater tends to

increase

(☐ increase / ☐ decrease) shortly after five P.M.

b. The flow of <u>industrial</u> wastewater tends to

decrease

(☐ increase / ☐ decrease) on the weekend.

c. The total flow of wastewater is

unlikely

(☐ likely / ☐ unlikely) to be constant throughout the day.

2.4 Some pollutants are carried along, suspended in the wastewater. Other pollutants are dissolved in the wastewater.

suspended

a. Sand and fine grit are (☐ dissolved / ☐ suspended) in the wastewater.

dissolved

b. When the wastewater contains salt, the salt is (☐ dissolved / ☐ suspended).

suspended

c. Passing the wastewater through a rack or screen removes some of the (☐ suspended / ☐ dissolved) material.

settle, or fall

d. If the wastewater is allowed to slow down to a low velocity, much of the remaining suspended solid material will _____.

cannot be

e. Dissolved material (☐ is also / ☐ cannot be) removed by settling processes in a treatment plant.

dissolved

f. The effluent from the settling tanks in a treatment plant still contains most of the (☐ dissolved / ☐ suspended) material that entered the plant.

2.5 Some pollutants are organic. Others are inorganic.

a. When organic material is heated in air, it _____ or at least chars.

burns

b. All organic material contains the element carbon, which may give it a _____ color when it is heated.

dark, or black

c. Sand is inorganic (not organic). Sand (☐ turns black / ☐ does not turn black) when it is heated.

does not turn black

d. If you are not sure whether a substance is organic, you just find out how it behaves when you _____ it.

heat, or burn

2.6 Most of the organic material in wastewater comes from things which are alive or which have been alive.

a. Left-over food (☐ is / ☐ is not) mostly organic.

is

b. Human and animal wastes (☐ are / ☐ are not) mostly organic.

are

c. Gravel (☐ is / ☐ is not) organic.

is not

are

d. Leaves from trees (are / are not) organic.

e. Bacteria and other microorganisms

are

(are / are not) organic.

2.7 Domestic wastes and most commercial wastes tend to be organic.

contains

a. Wastewater from a restaurant (contains / does not contain) organic materials.

contains

b. Wastewater from a food canning plant (contains / does not contain) organic materials.

c. In wastes produced over the weekend the composition tends to shift toward the organic side, because of the decrease from _____ and _____ sources.

industrial

commercial

2.8 Material suspended in wastewater may be either organic or inorganic.

a. Grass carried along by the water is (☐ organic /☐ inorganic).

organic

b. Suspended clay is (☐ organic /☐ inorganic).

inorganic

2.9 Dissolved material may also be organic or inorganic.

a. Salt is (☐ organic / ☐ inorganic).

inorganic

b. Alcohol is (☐ organic /☐ inorganic).

organic

3. Effects of Pollutants on Receiving Waters

3.1 <u>Organic</u> pollutants have many undesirable effects on receiving waters.

a. Organic material decays, producing foul _____.

odors

b. The decaying organic material also may give the water a _____ taste and may _____ its color.

bad
change, or
increase

c. Organic material provides food for bacteria and other microorganisms, and some of these microorganisms may cause _____ in man.

disease,
or harm

d. As the microorganisms feed on organic material, the oxygen in the water may be used up. The lack of oxygen can _____ fish.

kill

3.2 The effects of <u>inorganic</u> pollutants may be different from the effects of <u>organic</u> pollutants.

a. Some inorganic materials, such as arsenic, can _____ people.

kill

b. Some forms of nitrogen and phosphates act as fertilizers, and increase the growth of _____, which may choke up the receiving waters.

plants

3.3 Both organic and inorganic pollutants can be removed by treating wastewater before it is discharged into the receiving water.

racks, or screens

a. Much of the suspended and floating material is removed by passing the wastewater through _____ and then allowing it to _____.

settle

food

b. Much of the organic material is dissolved, or will not settle. Most of this organic material may be destroyed by using it as _____ for micro-organisms in a biological treating system.

purify

c. The processes used to treat wastewater are very much like the processes by which streams _____ themselves.

use

d. The treatment that should be used depends on the nature of the pollutants and their concentration in the wastewater, and on the intended _____ of the receiving waters.

increases

e. As the degree of treatment is increased, the cost of the treatment plant _____.

cost

quality

f. The degree of wastewater treatment is always a balance between the _____ of building the plant, and the _____ of the effluent that the plant has to produce.

SELF TEST I

1. Whenever the use of water is limited by the impurities it contains, the water is considered to be _____.

polluted

2. Pollution is caused principally by the activities of _____.

man, or humans

3. Small amounts of pollutants may not reduce the quality of water too far, since a stream can _____ itself.

purify, or clean

4. The character of a wastewater is determined by the relative amounts of waste from _____, _____ and _____ sources.

domestic
commercial
industrial

5. Sand and grit are (☐ organic / ☐ inorganic) materials.

inorganic

6. Wastes that come from domestic and commercial sources are mostly (☐ organic / ☐ inorganic).

organic

7. Suspended pollutants are (☐ easier / ☐ harder) to remove than dissolved pollutants are.

easier

odors

taste, or color

8. Organic pollutants may cause foul _____, and may give the water a bad _____.

9. Organic pollutants may also supply food for growth of _____ which can harm people.

bacteria, or microorganisms

10. Microorganisms feeding on organic pollutants may use up so much _____ that fish cannot live in the water.

oxygen

11. Inorganic pollutants may be poisonous, or they may cause growth of _____ that choke the receiving waters.

plants

12. Suspended pollutants are removed in treatment plants by screening and _____ processes.

settling

13. Organic pollutants are destroyed in treatment plants by the action of _____, which feed on them.

bacteria, or microorganisms

14. The degree of treatment of wastewater depends upon the type of pollutants, upon the intended _____ of the receiving water, and upon the total _____ of building the treatment plant.

use

cost

THOUGHT QUESTIONS

1. Garbage disposal units in kitchen sinks (☐ increase / ☐ decrease) the need for wastewater treatment, because.....

2. Why is pollution receiving much more publicity in this country in the last few years?

The answers to these questions are on the next page.

Answers to Thought Questions

1. Garbage disposal units increase the need for wastewater treatment. They put more pollutants into the wastewater.

2. Pollution is hitting the headlines because it's getting harder to find water of high enough quality for drinking water supplies and for industrial and recreational use.

PART II

FUNDAMENTALS OF BIOLOGICAL TREATMENT

THE DEGRADATION OF ORGANIC MATERIAL

4. The decay of organic wastes such as garbage and manure produces foul odors, attracts insects and rats, and causes health problems. The organic materials in wastewater can cause the same problems.

In a wastewater treatment plant, the organic material is removed or converted to less troublesome forms by microorganisms. This degraded organic material can then safely be discharged into the receiving waters.

In the most common test used to check the concentration of the organic content of wastewater, the organic material is converted by microorganisms that use up oxygen. The amount of oxygen used up in the conversion then indicates the level of organic pollution.

4.1 Organic material causes problems that are different from the problems caused by inorganic material. To decide what degree and type of treatment is needed, it is necessary to find out how much of the pollutants are organic.

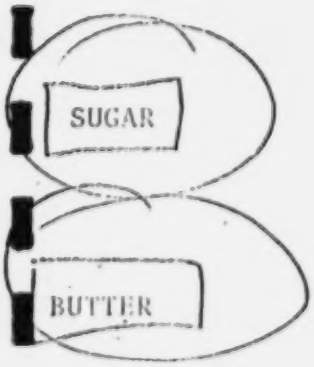
a. To decide whether a sample contains organic material, we can dry it, then heat it to see whether it _____.

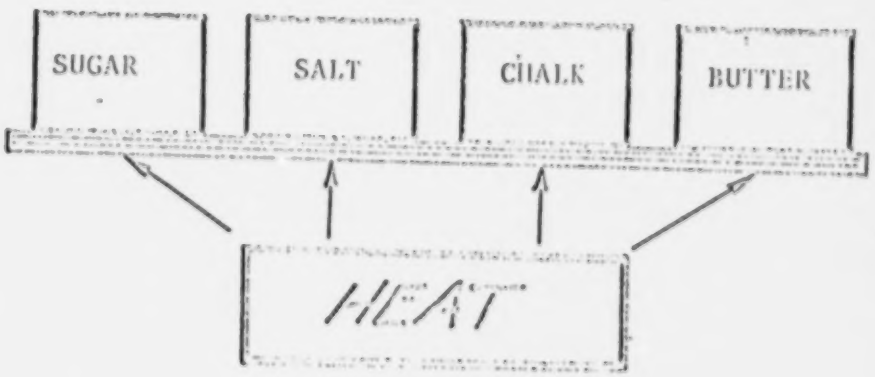
burns, or chars

b. Even if the substance just turns black, we would suspect that it was organic, because the black color probably indicates the presence of the element _____, which is in all organic substances.

carbon

c. Circle the substances that contain organic materials and will tend to burn or char.





d. When organic material burns completely, the carbon in it forms carbon dioxide (CO_2) by reacting with _____ from the air.

oxygen

4.2 Practically all organic materials also contain the element hydrogen.

a. When organic material burns completely, the hydrogen in it combines with _____ to form water (H_2O).

oxygen

b. It is not always easy to tell whether water is present, because at high temperatures the water turns to _____.

gas, or vapor, or steam

4.3 Burning may also be called oxidation. The word oxidation originally meant reaction with oxygen from the air.

a. When organic material has been burned completely, the carbon in it has been oxidized to form _____.

carbon dioxide, or CO_2

b. During burning, the _____ is oxidized to form water (H_2O).

hydrogen

4.4 Burning is not the only process that converts the carbon and hydrogen in organic material into CO_2 and H_2O.

a. Even when oxygen from the air is not used, any process that produces CO_2 and H_2O from organic material is called an _____ process.

oxidation

4.5 Oxidation processes may not oxidize the carbon and hydrogen completely.

a. In the burning process, a partial oxidation often produces poisonous carbon _____ instead of carbon dioxide.

monoxide

b. In carbon monoxide (CO), the carbon has combined with (☐ half / ☐ twice) as much oxygen as in carbon dioxide (CO_2). (HINT: look at the formulas!)

half

c. Carbon monoxide may be burned in air to form carbon _____.

dioxide

d. When CO is burned, it picks up the rest of the _____ that the carbon can hold, to form CO_2.

oxygen

4.6 Complete oxidation of organic material may take place in a long series of partial oxidation steps, forming CO or other products along the way.

a. Any complete or partial step that changes organic material in the direction of CO_2 and H_2O is called an _____ process.

oxidation

b. When organic material is oxidized, the products depend upon the method of oxidation, and upon the amount of _____ the organic material picks up.

oxygen

4.7 Organic material may contain other elements in addition to carbon and hydrogen. When the organic material is oxidized, any nitrogen in it may form nitrate (NO_3^-), nitrite (NO_2^-), free nitrogen (N_2), or other materials.

a. Any or all of these may be formed, depending upon the _____ of oxidation.

degree, or extent or type

b. The products formed from phosphorous and any other elements present also depend on how the _____ is supplied to react with the organic material.

oxygen

4.8 Air is not the only source of oxygen.

a. Many chemical compounds contain oxygen which is held loosely enough to be transferred, and these compounds can _____ organic material.

oxidize

b. In some cases, CO_2 itself can cause a partial oxidation, by releasing part of its _____ to organic material.

oxygen

4.9 Chemical compounds that oxidize organic material by any method are called oxidizing agents. In some kinds of oxidation, no oxygen is involved at all.

a. When no oxygen is involved, some other element may oxidize organic material, moving the carbon along the path toward the formation of _____ and moving the hydrogen toward _____.

CO_2
H_2O

b. Oxidizing agents (☐ always /☐ do not always) contain oxygen.

do not always

c. In a strictly chemical oxidation process, the organic material is oxidized by some chemical _____ agent.

oxidizing

4.10 Under the right conditions, most organic substances can act as oxidizing agents for organic material that is farther away from complete oxidation.

a. The substances formed in partial oxidation steps (☐ may /☐ cannot) help to oxidize fresh organic material.

may

5. Chemical Oxidation Tests

5.1 Chemical oxidations may be used as tests, to see how much of the organic material in wastewater can be oxidized. A chemical oxidation test measures the "Chemical Oxygen Demand" (COD) of the organic sample.

a. In a COD test, the wastewater is treated with a chemical _____ agent.

oxidizing

5.2 When a chemical oxidation proceeds too slowly to be practical, a catalyst (kat-a-list) may be added. The catalyst is a substance that speeds up the chemical reactions.

a. A catalyst in an oxidizion reaction may pick up oxygen, transferring it (☐ to / ☐ from) the oxidizing agent (☐ to / ☐ from) the organic material.

from
to

b. Because of the structures of the substances, the transfer of oxygen through the catalyst takes (☐ more / ☐ less) time than a direct transfer would.

less

c. A catalyst does not change the total <u>amount</u> of CO_2 produced in an oxidation; it just causes the CO_2 to be produced (☐ faster / ☐ slower).

faster

6. Biochemical Oxidation

6.1 When organic material decays, it goes through a series of oxidation steps. Biochemical oxidation takes place as the organic material is oxidized biologically. Biochemical oxidation is also called biodegradation, (bye-oh-degg-rah-day-shun). In biodegradation, enzymes (en-simes) produced by microorganisms act as catalysts.

a. In biodegradation, oxygen or some other oxidizing agent reacts with the organic material. The reaction is speeded up by the _____ produced by the microorganisms.

enzymes or catalysts

b. Biodegradation is a chemical oxidation taking place in a biological system, which explains why it is often called a _____ _____ oxidation.

biochemical

6.2 When organic pollutants are discharged into the receiving water, they are biodegraded by microorganisms in the water.

decreased

a. Because of the biodegradation that occurs, the supply of oxygen dissolved in the receiving water is (☐ increased / ☐ decreased).

kill
odors

b. The lack of oxygen in the receiving water may _____ fish, produce foul _____, and ruin the taste and color of the water.

decreased

c. The biodegradation would be (☐ increased / ☐ decreased) if the polluting material contained germicides.

kill, or harm

d. If the waste material contains pesticides or other poisonous chemicals, that are not degraded, the water may even be able to _____ people.

disease, or sickness

e. Some of the microorganisms that live on the organic pollutants may be able to cause _____ in people.

6.3 The biochemical processes in a wastewater treatment plant are designed to destroy most of the organic pollutants by oxidizing them, before the effluent is discharged into the receiving waters.

a. The organic pollutants serve as food for _____ in the treatment plant.

micro-organisms

b. In biodegradation, organic material that already has a sizeable amount of oxygen built into it is degraded (☐ faster / ☐ slower) than material that has less oxygen in it.

faster

c. Oil and grease contain <u>less</u> oxygen than carbohydrates like sugar. Therefore, oil and grease are biodegraded (☐ faster / ☐ slower) than sugar.

slower

6.4 Protein, and other material containing nitrogen is generally biodegraded faster than oil or fat, but slower than carbohydrates like sugar.

a. In a wastewater containing a mixture of fat, carbohydrate and protein, the _____ part will be degraded most rapidly, then the _____ part. The water may have passed through the treatment plant before much of the _____ is degraded.

carbohydrate

protein

fat

6.5 The biochemical oxygen demand (BOD) is the amount of oxygen used up in the oxidation of a sample of wastewater by microorganisms, when there is plenty of oxygen available.

a. The BOD test shows how much oxygen is needed to oxidize the _____ material in the sample.

organic

b. The oxygen used up in the BOD test indicates the amount of biodegradable _____ material in the wastewater.

organic

c. The effluent from a wastewater treatment plant should have a much (☐ higher / ☐ lower) BOD than the influent wastewater entering the plant.

lower

d. The BOD measures the chemical oxidation occuring in a biological system, and is therefore called the _____ oxygen demand.

biochemical

e. To get results that are close to the results from a biological treatment plant, we should use a (☐ BOD / ☐ COD) test, because the degradation is carried out by _____, just as it is in the treatment plant.

BOD

icroorganisms

SELF TEST II

carbon dioxide (CO_2) water(H_2O)

1. When an organic material burns completely, the carbon in it is changed to _____ _____, and the hydrogen forms _____.

oxidation

2. Any process that converts carbon to CO_2 is an _____ process.

is also

3. When CO is formed from carbon, the process (☐ is also /☐ is not) an oxidation.

less

4. The conversion of CO to CO_2 uses up (☐ more /☐ less) oxygen than the conversion of C to CO_2.

agent

5. A chemical compound that oxidizes organic material is called an oxidizing _____.

sometimes

6. An oxidation reaction (☐ always /☐ sometimes) involves the transfer of oxygen.

catalyst

7. To speed up a reaction, a _____ may be used.

enzyme

8. A biological catalyst is called an _____.

9. A biochemical oxidation may also be called a

biodegradation

_____.

10. In a biochemical oxidation, proteins are degraded

faster, slower

_____ than fats, but _____ than carbohydrates.

biochemical, demand

11. BOD stands for _____ oxygen _____.

THOUGHT QUESTIONS

1. In the "volatile solids" test, solids are heated to a high temperature (600°C) in air, to see how much of the material burns or evaporates. The volatile solids test gives a rough measure of the amount of _____ material in the solids.

2. When raw sewage is discharged into a stream, a section of the stream below the point of discharge may give off foul odors, and have no fish, but further downstream conditions may be normal.

   a. What is the main effect of the sewage, that causes the damage to the stream?

   b. What has happened where the stream returns to normal?

The answers to these questions are on the next page.

Answers to Thought Questions.

1. organic

2. a. The degradation of the organic material uses up the stream's supply of oxygen.

   b. When the microorganisms in the stream have degraded nearly all of the organic material, they use up less oxygen. As the stream dissolves more oxygen from the air, it "purifies itself".

HOW MICROORGANISMS USE ORGANIC MATERIAL

7. There are many types of microorganisms in the biological treatment section of a wastewater treatment plant. These microorganisms feed on the pollutants in the wastewater. Each type of microorganism has its own nutritional requirements. Some feed on part of the raw waste material; some feed on the partially degraded material produced by other microorganisms; some feed on the other microorganisms themselves.

In an effective wastewater treatment plant, the action of the various types of microorganisms together produces an effluent with a very low organic pollution level.

W.1 The many types of microorganisms in a biological treatment system feed on the organic material in the wastewater. This treatment can be effective only if the microorganisms as a group can furnish the correct enzymes to permit the oxidations to take place in a reasonable length of time.

a. Microorganisms "digest" the organic material in a series of partial _____ steps.

oxidation

b. The enzymes produced by the microorganisms speed up the reaction of the organic pollutants with oxygen or some other oxidizing _____.

agent

c. Oxidation reactions produce energy. When organic material burns, the energy is given off as light and _____.

heat

d. Some of the energy produced in biodegradation causes the temperature of the wastewater to _____, and some of the energy is used in the life processes of the _____.

increase

micro-organisms

17.2 The microorganisms use part of their food for energy, and part to build new cell material.

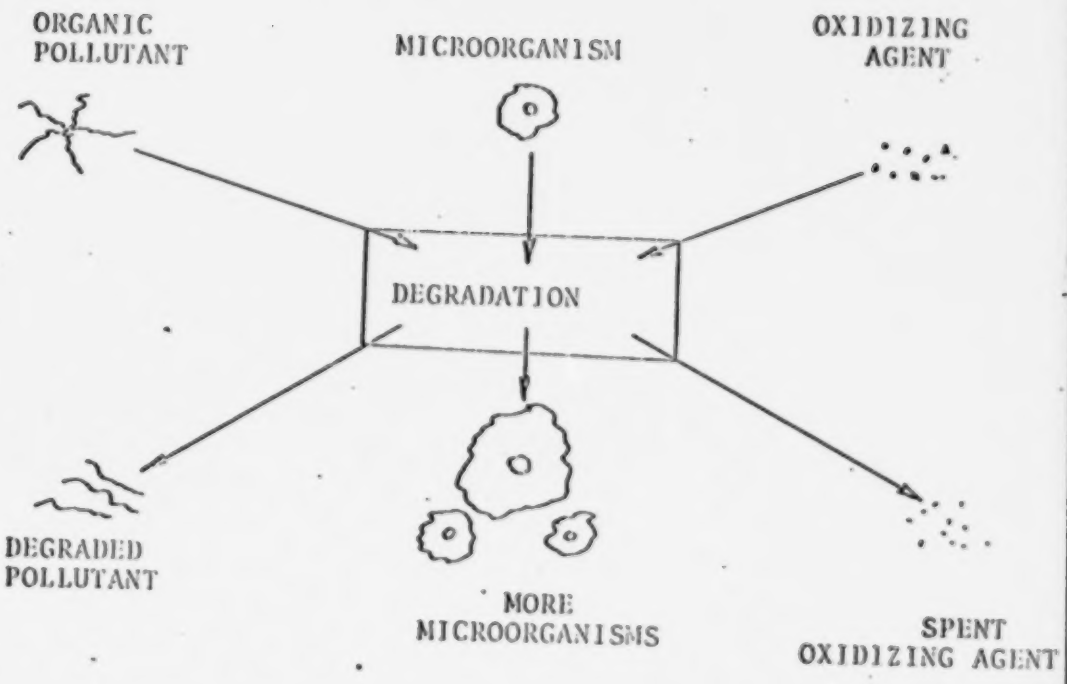
a. As the microorganisms degrade the organic pollutants, the number and size of the microorganisms becomes _____.

greater

b. Without a sufficient food supply the microorganisms will not _____.

grow

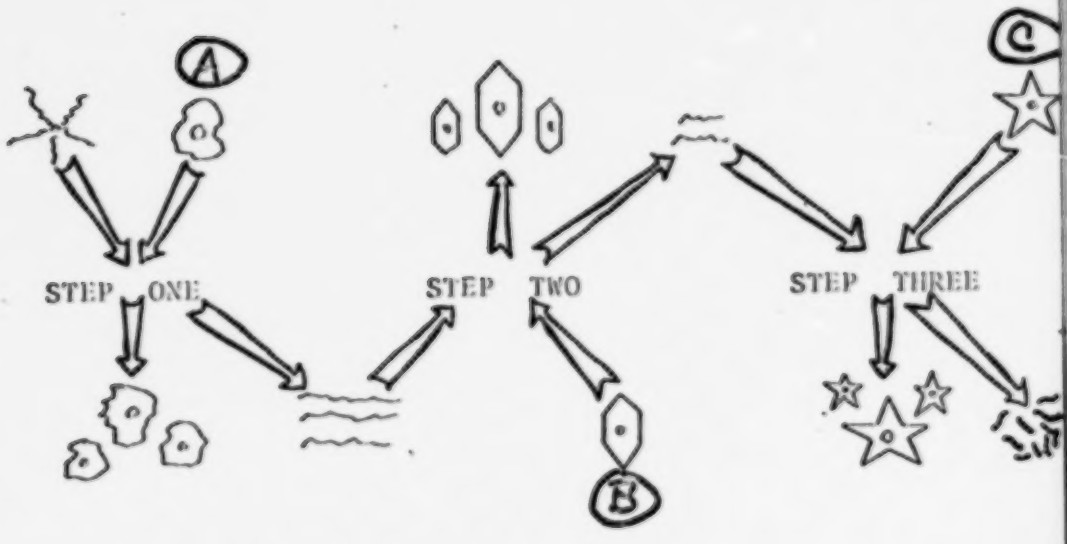
7.3 Here is a diagram showing what happens in each step of a biological treatment system.



a. In a single step, one type of microorganism degrades a particular type of pollutant, and uses up a particular type of _____ _____ in the reaction.

oxidizing agent

7.4 Since there are many types of microorganisms in a biological treatment system, the degradation of the pollutants may involve many steps:



a. The picture indicates that the degraded pollutants produced as waste material by one type of microorganism may be used as _____ by another type of microorganism.

food

7.5 The various types of microorganisms in a biological treatment system depend on each other. A co-operative relationship such as the ones between these microorganisms is called symbiosis (sim-bye-oh-sis).

food

a. Organism A supplies _____ for organism B. Organism B keeps organism A from

wastes

being "smothered" in the _____ it produces.

alive

b. One member of the symbiotic partnership might not even be able to stay _____ without the others.

8. Physical Characteristics

8.1 Microorganisms such as bacteria have no mouths. They take in food directly through their "skin."

a. There is no way for the microorganisms in a biological treatment system to take in (☐ gaseous /☐ liquid /☐ solid) food through their "skin".

solid

b. Even when nutrients and oxidizing agents are present, microorganisms may not be able to grow unless the nutrients and oxidizing agents are in a form that they can _____.

use or absorb

8.2 Before undissolved solid wastes can be absorbed, they have to be partly digested to form substances that dissolve in water.

a. The breakdown of the solids begins (☐ outside /☐ inside) the cells of the microorganisms.

outside

b. The enzymes released by the microorganisms must be able to act as _____ to speed up the "liquifaction" of the solid organic substances in the wastewater.

catalysts

c. If a particular solid organic substance is not "liquified," the microorganisms in the biological treatment system (☐ cannot / ☐ may still) use it as food.

cannot

8.3 Gases such as oxygen have to be dissolved before the microorganisms can use them.

a. Even in air, a microorganism that needs oxygen cannot grow unless there is some _____ present, for the oxygen to dissolve in.

moisture

8.4 Like other living things, microorganisms are made up of cells. Unless the food supply contains all of the elements needed to form cells, the microorganisms cannot grow, even if they can stay alive.

a. The only healthy growing microorganisms in a biological treatment system are the ones that can get all the elements they need from the nutrient material suspended or dissolved in the _____ that flows through the system.

wastewater

b. Some kinds of wastewater have too little nitrogen and phosphorous, and these elements may actually have to be _____ to make biological treatment effective on such wastewater.

added

9. Important classifications

9.1 Different types of microorganisms need different types of nutrients. Heterotrophic (hetter-oh-trŏfik) microorganisms get carbon by feeding on organic material, and autotrophic microorganisms get all of their nutrients from inorganic material such as CO_2.

a. In a wastewater treatment plant, some microorganisms supply nutrients for others, in a symbiotic _____ partnership.

b. The treatment of organic pollutants is brought about only by the (☐ heterotrophic / ☐ autotrophic) microorganisms in the system.

heterotrophic

c. CO_2 produced as waste by heterotrophic microorganisms may be used as food by the _____ microorganisms.

autotrophic

d. An effective biological treatment system usually contains both _____ and _____ microorganisms.

heterotrophic

autotrophic

9.2 Microorganisms are also classified according to the type of oxidizing agent they use. For example, the oxidizing agent may be nitrate, or organic material, or oxygen dissolved in the wastewater.

depend

a. The products of a biodegradation step (☐ depend / ☐ do not depend) on the type of oxidizing agent used.

9.3 Aerobic (ay-row'bik) microorganisms can use only uncombined ("free") oxygen as an oxidizing agent.

air

a. They usually get their oxygen from the _____, as people do.

dissolved

b. Air is a gas, so the aerobic microorganisms cannot use the oxygen in it until it has been _____.

9.4 On the other hand, anaerobic (anna-row-bik) microorganisms are unable to use oxygen in its uncombined form, and even relatively small amounts of uncombined oxygen may poison them.

die

a. Anaerobic microorganisms _____ when they are exposed to air.

9.5 Facultative (fak-ull-tay-tiv) microorganisms can function with or without uncombined oxygen.

a. If a great amount of dissolved oxygen from the air is available, the facultative microorganisms behave like _____ microorganisms.

aerobic

b. When there is no dissolved _____ available, the facultative microorganisms behave like _____ microorganisms.

oxygen

anaerobic

9.6 In a system where there is dissolved oxygen, but where the supply is sometimes completely used up, microorganisms that are strictly aerobic would die when the oxygen supply is low. Microorganisms that are strictly anaerobic would die when the oxygen supply is high. Neither type can survive.

a. The microorganisms that survive in such a system are the _____ microorganisms.

facultative

9.7 Denitrifying (dee-night-ri-fy-ing) autotrophs use nitrate as an oxidizing agent, releasing the nitrogen, which escapes into the air.

a. Denitrifying autotrophs keep the nitrate content

low

(☐ high / ☐ low) in the treatment system.

b. Nitrates are used in fertilizers. A high nitrate

increase

content tends to (☐ increase / ☐ decrease) plant growth.

c. Plant growth choking the receiving waters is an indication that conditions in the wastewater treatment system do not allow

autotrophs

(☐ heterotrophs / ☐ autotrophs) to grow well.

9.8 The population of microorganisms in any wastewater treatment plant contains many types.

a. The types of microorganisms that grow best in a treatment plant depend upon the kinds of nutrients and oxidizing agents in the _____ that is flowing through the plant.

wastewater

SELF TEST III

enzymes, or catalysts

1. Microorganisms produce _____ which speed up oxidation reactions to a practical rate.

before

2. The enzymes start to work on solid nutrients (☐ before / ☐ as soon as) the nutrients enter the bodies of the microorganisms.

oxidizing

water

3. In addition to a supply of food, and the enzymes they produce themselves, the microorganisms need some kind of _____ agent; they also need _____ for gases and solids to dissolve in.

many kinds

4. A biological treatment system contains (☐ only one kind / ☐ many kinds) of microorganisms.

help

5. Symbiotic microorganisms _____ each other.

heterotrophs

6. Organic material is the only source of carbon for (☐ heterotrophs / ☐ autotrophs).

autotrophs

7. Nitrates are converted to uncombined nitrogen by some types of (☐ heterotrophs / ☐ autotrophs).

8. Uncombined oxygen, usually dissolved out of the _____, is necessary for _____ microorganisms.

air, aerobic

9. Microorganisms which cannot use uncombined oxygen are _____ microorganisms.

anaerobic

10. Microorganisms that can grow with or without uncombined oxygen are _____ microorganisms.

facultative

THOUGHT QUESTIONS

1. Nitrogen and phosphorus may have to be added to some kinds of wastewater to keep the microorganisms in the treatment plant healthy and growing. If these elements are added when they are <u>not</u> needed they might pollute the receiving water. How could you tell if this was happening?

2. Is wastewater warmer or colder than drinking water would be under the same conditions? Why?

3. In a deep pond containing wastewater, sometimes both aerobic and anaerobic microorganisms are growing a the same time, but not in the same part of the pond. Where are the anaerobic microorganisms growing? Why?

The answers to these questions are on the next page.

Answers to Thought Questions.

1. If the effluent contains too high a level of N and P, it may cause undesirable plant growth in the receiving waters.

2. Wastewater is warmer, because some of the energy produced by biological oxidation shows up as heat.

3. Anaerobic microorganisms grow near the bottom of the pond. Oxygen from the air may not circulate down very far from the surface.

10. Under favorable conditions, starting from a few individuals, a population of microorganisms grows slowly, then explosively, as long as the food supply holds out. When growth produces too many microorganisms for the supply of nutrients, the population gradually falls off.

In a wastewater treatment plant, the microorganisms are kept growing vigorously by removing enough of them to keep in step with the nutrient supply.

The various types of microorganisms require different types of nutrients. The composition of the population of microorganisms in the treatment plant shifts with changes in the composition of the wastewater.

10.1 Microorganisms are practically everywhere.

a. A colony of some type of microorganism seems to spring up almost anywhere, where there is moisture, some type of _____ agent, and some kind of _____.

oxidizing

food, or nutrient

10.2 Colonies are started by "seed" microorganisms which are always present in the air, the water and the soil.

a. A seed microorganism cannot start a colony unless the nutrients and oxidizing agents are available in a form it can _____.

use, or absorb

b. When seed microorganisms are introduced into a new wastewater treatment plant, there is a lag while they _____ to the conditions in the system.

adjust, or adapt

c. If the seed is taken from surroundings which are like those in the treatment plant, the lag period is relatively (☐ short / ☐ long).

short

10.3 Before a treatment plant is built, the water that will receive its effluent contains microorganisms growing under conditions similar to the conditions that will exist in the treatment system.

seed

a. The receiving water is thus a good place to get microorganisms to use as _____ for the treatment system.

slow

b. Even when the treatment plant has been well seeded, growth is very _____ during the lag phase.

die

c. Some types of microorganisms may <u>not</u> be able to adapt to conditions in the treatment plant, and these microorganisms will _____.

increase

d. As each particular type of microorganism adapts to the new conditions, its rate of growth and reproduction begins to _____ rapidly.

lag

e. The size and number of the microorganisms increase as the _____ phase ends and the growth phase (or logarithmic phase) begins.

growth

f. The types of microorganisms that adapt most rapidly enter the _____phase first.

10.4 The microorganisms that enter the growth phase first may kill those that adapt more slowly.

The fast-growing microorganisms may produce wastes that poison the others, or the fast-growing ones may use up all of the available food or oxygen.

a. If enough food is present and microorganisms can be removed to prevent overcrowding, the _____ phase can be maintained all the time.

growth

b. Even during the growth phase, some microorganisms die, but they are more than replaced by the increased _____ of the other microorganisms.

reproduction or multiplication

10.5 During the growth phase, some of the food taken in by the microorganisms is stored in their cells.

a. The stored food can be used up during periods where there is too _____ food in the wastewater.

little

b. If the food supply is limited or the wastes produced by the microorganisms build up beyond a certain level, growth and reproduction begin to _____.

decrease

10.6 As growth and reproduction decrease, a stationary phase is reached.

a. In the stationary phase, new microorganisms are produced just fast enough to replace those that _____. (die)

b. If the food supply continues to decrease, the microorganisms begin to use up some of the food that they have _____. (stored)

c. If the food supply falls low enough, the microorganisms pass from the growth phase through the _____ phase into the death phase. (stationary)

10.7 In the death phase, the microorganisms live on stored food, and "cannibalize" other microorganisms.

a. The main types of microorganisms that survive in the death phase have to be able to use other microorganisms as _____. (food)

b. If no food is added, eventually all of the cell material is converted to forms that cannot be used, and practically the entire population of microorganisms _____. (dies)

10.8 The microorganisms should be maintained in the growth phase in biological treatment systems.

a. The wastewater should contain a constant supply of _____, and oxygen or other oxidizing agents.

food

b. To keep the population of microorganisms from out-growing the food supply, microorganisms must be continually (☐ added /☐ removed) as growth continues.

removed

10.9 A sudden increase in the food supply may cause an increase in the growth of one type of microorganism until it crowds out the others.

symbiotic

a. Such a "shock load" may disturb the _____ partnerships among the many types of microorganisms in the treatment plant.

b. A sudden decrease in the food supply may cause many types of microorganisms to pass beyond the growth phase, into the stationary phase, or even into the _____ phase.

death

steady

shock

growth

c. In biological wastewater treatment, the supply of organic material should be kept as _____ as possible, to avoid "_____ loads" and to keep the microorganisms in the _____ phase.

SELF TEST IV

1. The waters that receive the wastewater before the treatment plant is built make a good source of _____ for the treatment system.

seed

2. A population of microorganisms with a limited food supply goes through four phases:

lag
adapt

a. First, the initial _____ phase, while the microorganisms_____ to their surroundings.

growth
growth or reproduction

b. Second, the _____ phase, in which the rate of _____ is much greater than the death rate.

stationary
die

c. Third, the _____ phase, in which the microorganisms reproduce just fast enough to replace those that _____.

death
feed

d. Fourth, the _____phase, in which some microorganisms _____ on others.

3. The various types of microorganisms in a treatment plant ([ ] all/[ ] do not) pass through the four phases at the same rate.

do not

stored

4. During the growth phase, some food is _____ for later use.

shock

grow, or multiply

5. A sudden increase in the food supply, or a "_____ load", may cause some types of microorganisms to _____ too rapidly.

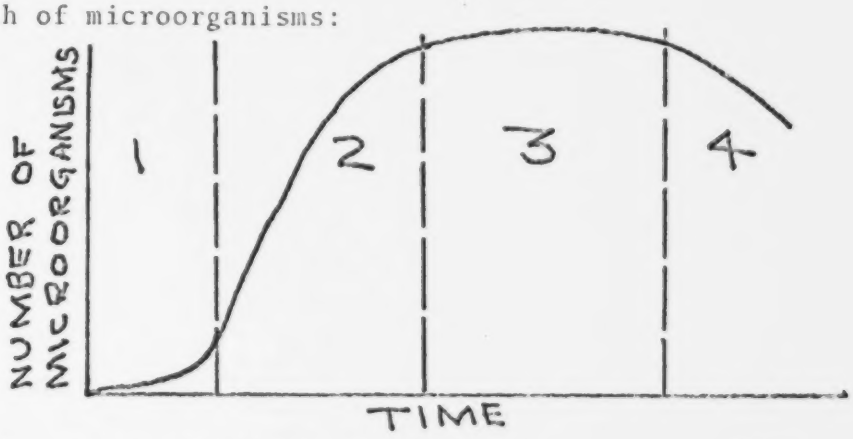
constant, or steady

removed

6. To maintain the effectiveness of biological treatment, the supply of organic material should be as _____ as possible, and some micro-organisms should continually be _____.

THOUGHT QUESTIONS

1. Here is a graph that illustrates the stages in the growth of microorganisms:



a. The stage labelled "1" is the _____ phase.

b. The stage labelled "2" is the _____ phase.

c. The stage labelled "3" is the _____ phase.

d. The stage labelled "4" is the _____ phase.

2. The number of microorganisms is increasing fastest in the stage labelled _____.

3. The number of microorganisms is greatest in the stage labelled _____.

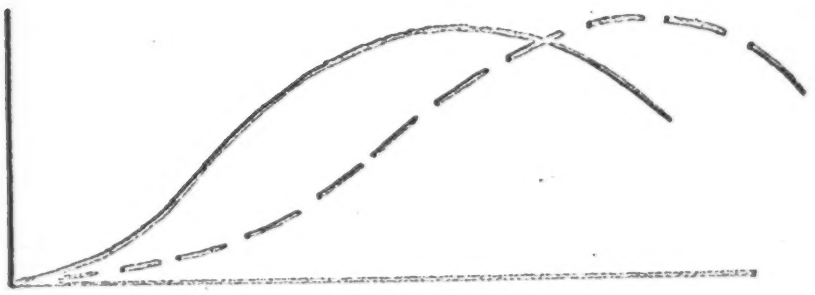
4. On the graph above, draw a dotted curve to show what would happen if the microorganism adapted more slowly.

1. a. lag
   b. growth, or logarithmic
   c. stationary
   d. death

2. 2

3. 3

4.



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11. Even when the supply of nutrients is satisfactory, microorganisms can grow only when environmental conditions are in the right range. The temperature and the level of acidity or alkalinity are of greatest importance. To keep a wastewater treatment plant operating effectively, these conditions must be kept at levels that permit rapid growth of the microorganisms needed to produce an effluent of the required quality.

11.1 Metabolism is the name given to the complicated chemical reactions making up the life processes of living things. Changes in the rates of these metabolic reactions can decrease or stop the growth of microorganisms.

a. Metabolic reactions provide the microorganisms with material to build new _____, and also provide them with the _____ they need to keep themselves warm and active.

cells

energy

12. Effect of temperature

12.1 Chemical reactions run more slowly at lower temperatures.

a. As the temperature drops, the complicated reactions that make up the _____ of a microorganism slow down.

metabolism

b. Even if the temperature does not fall far enough to kill the microorganisms, their rate of growth becomes _____.

lower

c. At low temperature, microorganisms may become dormant, and their growth may _____ altogether.

stop

d. Dormant microorganisms are not dead. They have just stopped _____.

growing

e. When conditions become more favorable, the dormant microorganisms start to _____ again.

grow

12.2 On the other hand, high temperature may speed up metabolic reactions too much, or may destroy the enzymes that catalyze them, or may even destroy the microorganisms completely.

a. In any case, when the temperature gets too high, microorganisms _____.

die

12.3 For most aerobic microorganisms, the best growth temperatures are around 75-85°F (25-30°C).

a. In northern climates, aerobic microorganisms grow best at (☐ summer / ☐ winter) temperatures.

summer

b. The best growth temperature is somewhere between the temperature where the microorganisms become _____ and stop growing, and the temperature that can _____ them.

dormant

kill

12.4 The various types in the mixed population in a treatment system are not all affected the same way by temperature changes. Small changes in temperature do not destroy the effectiveness of biological treatment if the population contains any useful types of microorganisms that function well at the new temperature.

a. Even in winter, the flow of wastewater through a treatment plant usually keeps the temperature high enough that the aerobic microorganisms do not all become _____, and some growth continues.

dormant

b. Biological treatment is still effective as long as some kinds of aerobic microorganisms in the mixed population are _____ well.

growing

c. Artificial methods of heating (☐ are / ☐ are not) needed for work with aerobic microorganisms.

are not

12.5 The organic material in the solids from the settling tanks can often be degraded more effectively by anaerobic microorganisms. The anaerobic microorganisms most used in wastewater treatment seem to grow best at temperatures between 90°F and 100°F (30-35°C).

a. This anaerobic digestion takes place only when there is no _____ present.

oxygen

b. These anaerobic microorganisms prefer (☐ higher / ☐ lower) temperatures than aerobic microorganisms do.

higher

c. Even in summer, some method of heating is generally needed to keep (☐ aerobic / ☐ anaerobic) microorganisms growing at a reasonable rate.

anaerobic

13. Effect of pH

13.1 Even at favorable temperatures conditions in the wastewater may be unfavorable to growth.

a. Many types of chemical compounds can poison microorganisms, and _____ the effectiveness of the biological treatment system.

decrease

13.2 Strong acids, such as sulfuric acid, or even weak acids such as vinegar and lemon juice, may kill microorganisms.

a. Although acid may not kill all kinds of microorganisms, it can upset the _____ partnerships in a treatment system.

symbiotic, or cooperative

13.3 Acids cause damage by releasing hydrogen ions (H^+).

a. Stronger acids are more harmful because they release (☐ more / ☐ fewer) H^+ ions.

more

13.4 Caustic soda, or lye, and other strong alkalies are also harmful to microorganisms.

a. Weaker alkalies such as lime cause (☐ more / ☐ less) harm to biological systems than lye does.

less

b. Alkalies are sometimes called bases. (☐ Vinegar / ☐ Lye) is one type of base.

Lye

13.5 Alkalies or bases, release hydroxyl ions, (OH^-).

different from

a. Alkalies cause damage by chemical reactions which are (☐ the same as / ☐ different from) the reactions of acids.

13.6 Pure water has very small numbers of H^+ and OH^- ions in it, in equal amounts. Whenever there are H^+ ions and OH^- ions in the same solution, most of them combine to form water. When enough acid is added to an alkali to make equal numbers of H^+ and OH^- ions, the solution is neutral.

are not

a. The amounts of H^+ and OH^- in pure water (☐ are / ☐ are not) great enough to cause trouble.

less

b. Acid added to alkali makes the alkali (☐ more / ☐ less) harmful.

acidic

c. A neutral solution is neither _____ nor alkaline.

H^+, OH^-

d. The pH indicates whether the solution contains more _____ ions or more _____ ions.

13.7 The pH of most solutions is somewhere between 1 and 13. Pure water has a pH of 7.

a. A solution with a pH of 1 is very acidic; a solution with a pH of 13 is very _____.

alkaline, or basic

b. Any solution with a pH of 7 is (☒ acidic / ☒ alkaline / ☐ neutral).

neutral

c. A solution containing a large amount of a strong alkali, such as lye, has a pH near (☐ 1 / ☐ 7 / ☐ 13).

13

d. Wastewater with a pH of 6 is (☐ strongly / ☐ weakly) (☐ acidic / ☐ alkaline).

weakly acidic

e. Wastewater that is only slightly basic would have a pH around _____.

8 or 9

13.8 Different types of microorganisms require different pH conditions.

a. Some microorganisms do well at a pH around 3 or 4, in fairly (☐ acidic / ☐ alkaline) water.

acidic

b. Microorganisms that require a pH around 9 grow (☐ well / ☐ poorly) in somewhat alkaline solutions.

well

c. The microorganisms in the usual wastewater treatment system require neutral water around a pH of _____.

7

d. Some microorganisms in wastewater treatment systems produce acids, which could shift the pH (☐ above / ☐ below) 7.

below

e. When the pH of the wastewater is too low, it may be necessary to add some _____ to the system to neutralize some of the _____.

alkali or base

acid

13.9 Wastewater may contain substances which can remove limited amounts of added H^+ or OH^- ions. These substances make it possible to add a little acid or alkali without changing the pH of the water.

Substances that pick up the added H^+ or OH^- ions are called buffers.

a. If the wastewater contains a large amount of buffering material, its pH will tend to be _____, whether it is acidic, alkaline, or neutral.

constant, or steady

b. The alkalinity of the wastewater indicates how much acid can be added before the pH shifts (☐ above / ☐ below) 7.

below

c. Wastewater with a pH only slightly above 7 may still have a high alkalinity, if it requires a great amount of _____ to neutralize it.

acid

d. Water with a pH of 13 could be neutralized with a relatively small amount of acid, if the water had a low degree of _____.

alkalinity

e. The pH indicates only the relative numbers of _____ and _____ ions in the wastewater.

H^+, OH^-

f. The alkalinity indicates the amount of _____ substance in the wastewater.

buffer

13.10 Both pH and alkalinity are important in biological treatment.

7

a. The pH should be around _____.

high

b. Since the pH of the wastewater should stay steady, the alkalinity should be (☐ high / ☐ low).

acids

c. A high degree of alkalinity helps to control pH changes that could be caused by microorganisms that form _____ from neutral substances.

adjust or adapt

d. In biological treatment systems, rapid changes in pH are particularly harmful because the microorganisms require some time to _____ to new conditions.

1. At low temperatures, microorganisms become _____, even if they are not killed.

dormant

2. Most of the effects of temperature on microorganisms are the result of speeding up or slowing down the chemical _____ that make up their _____.

reactions
metabolism

3. Heating is generally needed in a treatment system, to keep the (☐ aerobic /☐ anaerobic) microorganisms healthy.

anaerobic

4. The relative numbers of H^+ ions and OH^- ions in a solution determines the _____ of the solution.

pH

5. pH values generally range between _____ and _____.

1

13

6. A solution with a pH of 7 is called a _____ solution

neutral

7. Strong alkalies, such as lye, make the pH (☐ higher /☐ lower).

higher

8. Acid-forming microorganisms tend to (☐ raise / ☐ lower) the pH, but the presence of _____ substances helps to keep it under control, or small amounts of _____ may be added.

lower

buffer

alkali, or base

9. Conditions in a treatment system are more favorable if the system has a high (☐ pH / ☐ alkalinity).

alkalinity

THOUGHT QUESTIONS

1. Why do we use heat for sterilization, instead of extreme cold?

2. Most suspended solids are settled out of wastewater. The organic portion of the solid material is treated by anaerobic microorganisms in a process called digestion, which produces acids at one stage of the biodegradation.

   a. Is a digester run open or closed?

   b. Does the pH in the digester tend to get higher or lower than the pH eleswhere in the treatment system?

Answers appear on the following page.

Answers to thought questions.

1. Heat kills microorganisms, but freezing may only preserve them.

2. a. Closed (to keep air away from the anaerobic microorganisms).

   b. lower

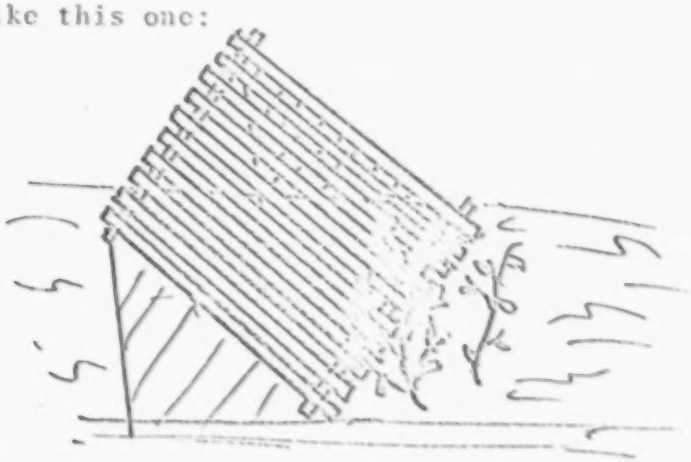
PART III

APPLICATION OF BASIC PRINCIPLES

PRIMARY TREATMENT

14. The type and degree of wastewater treatment depends on the type and quantity of pollutants, and upon the quality needed in the effluent.

14.1 At the inlet of most treatment plants, you will find bar racks, like this one:



large a. A bar rack can be used to remove (☐ large / ☐ small) solid objects from the wastewater.

plug or damage b. If objects like tree branches and old rubber boots were not removed from the water, they could _____ the pumps and other equipment in the treatment plant.

protect c. Screens are also used at the inlet of a treatment plant, to help _____ the plant equipment.

protecting d. Grinding up the large solid objects is another way of _____ the plant equipment.

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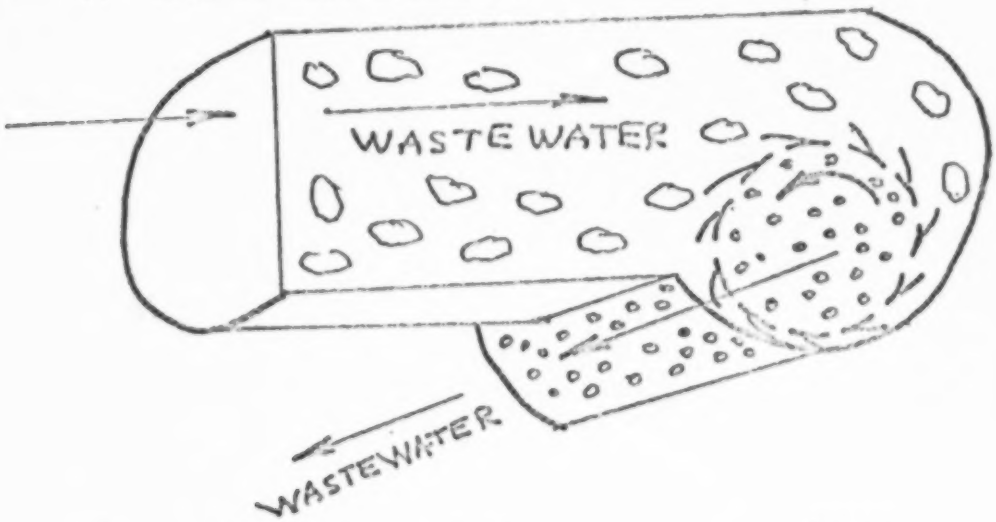
e. Look at this comminutor:



grind or pulverize

The comminutor is used to _____ large pieces of solid material.

racks, screens

comminutors

f. Practically all wastewater treatment plants have some combination of _____, _____ and _____ to protect the equipment.

14.2 Fast-moving wastewater can carry many kinds of solid material suspended in it. Some of the suspended solids are settleable, and some are not.

a. Some organic material, like wood, has a specific gravity that is lower than the specific gravity of water. Such material tends to _____ instead of settling.

float

b. Inorganic material like sand and grit does not float, because its specific gravity is too (☐high /☐ low).

high

c. Sand and other solids with a high specific gravity can be carried along if the wastewater is moving _____ enough.

fast

d. In a treatment plant, the wastewater is slowed down to a low velocity, to let some of the solids _____.

settle

e. Solids with higher specific gravity settle (☐faster /☐ slower).

faster

slower

f. Fine particles of sand and grit settle out (☐ faster / ☐ slower) than large particles.

slowly

g. Particles as fine as baby powder cannot be removed by just slowing the water down, because they settle too _____.

high, large or big

h. Suspended solids are settleable when their specific gravity is _____ enough, and when the particles are _____ enough.

14.3 Chemicals are sometimes added to <u>flocculate</u> fine suspended particles, to form large <u>flocs</u> or clumps.

faster

a. Flocculation makes the solids settle (☐ faster / ☐ slower), because of the increase in size.

14.4 Settling treatment alone does not usually solve pollution problems completely.

a. Settling removes a little of the fine material and dissolved material, because it _____ to the falling particles.

sticks or clings

b. Most of the fine and dissolved material (☐ is /☐ is not) removed in the settling tanks.

is not

c. More of the fine material can be removed when chemicals are added to _____ the particles.

flocculate or clump

d. The sludge that settles out in the settling tanks attracts flies, and produces foul odors, because of the (▭ organic /▭ inorganic) material in it.

organic

e. Settling treatment alone leaves some fine and dissolved material in the _____ from the plant, and some undesirable organic material in the _____ that settles out in the settling tanks.

effluent

sludge

14.5 Bacteria and other microorganisms in the treatment system destroy some of the organic material in the same way that a stream purifies itself.

a. The amount of undesirable organic material in the effluent and sludge together is (☐ lower than / ☐ the same as) the total amount in the influent.

lower than

b. The quality of the effluent from settling treatment may be satisfactory, if the action of the _____ has destroyed most of the organic material.

bacteria or microorganisms

14.6 The organic content of the raw sludge from the settling tanks is high enough to cause disposal problems. Raw sludge is most often treated by a digestion process before final disposal.

a. Anaerobic microorganisms act on the sludge during digestion, so oxygen is (☐ needed / ☐ kept away).

kept away

b. The digesters are (☐ open / ☐ closed) tanks.

closed

c. To make the anaerobic microorganisms grow best, the digesters are kept at (☐ room temperature / ☐ around 95°F).

around 95°F

14.7 Three types of processes take place in the digester.

1. Easily degraded material, such as sugar, is converted to CO_2, H_2O and some kinds of acids.
2. The acids formed in the first process are used up in further degradation reactions.
3. Some of the organic material is converted to methane (CH_4), which is the main substance in natural gas.

low (too much acid!)

a. If process 1 goes faster than process 2, the pH in the digester gets too (☐ high / ☐ low).

3

b. The gases produced in the digester may be used for fuel, because of the product from process (☐ 1 / ☐ 2 / ☐ 3).

14.8 Part of the liquid carried along with the sludge separates in the digester. Digested sludge still contains too much water for easy handling, and some type of dewatering process is needed before final disposal.

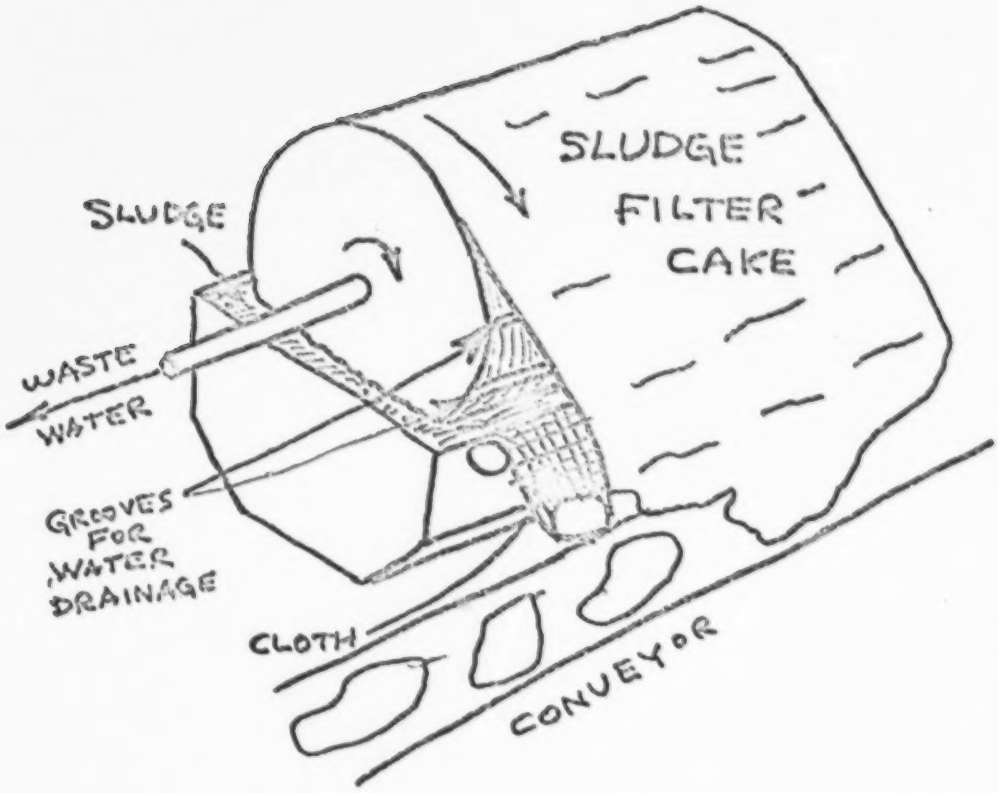
a. Digested sludge can be poured on sand beds, to allow the _____ to seep out of the sludge into the sand.

water

b. The top of the sand bed is scraped off to remove the sludge solids when they are _____.

dry

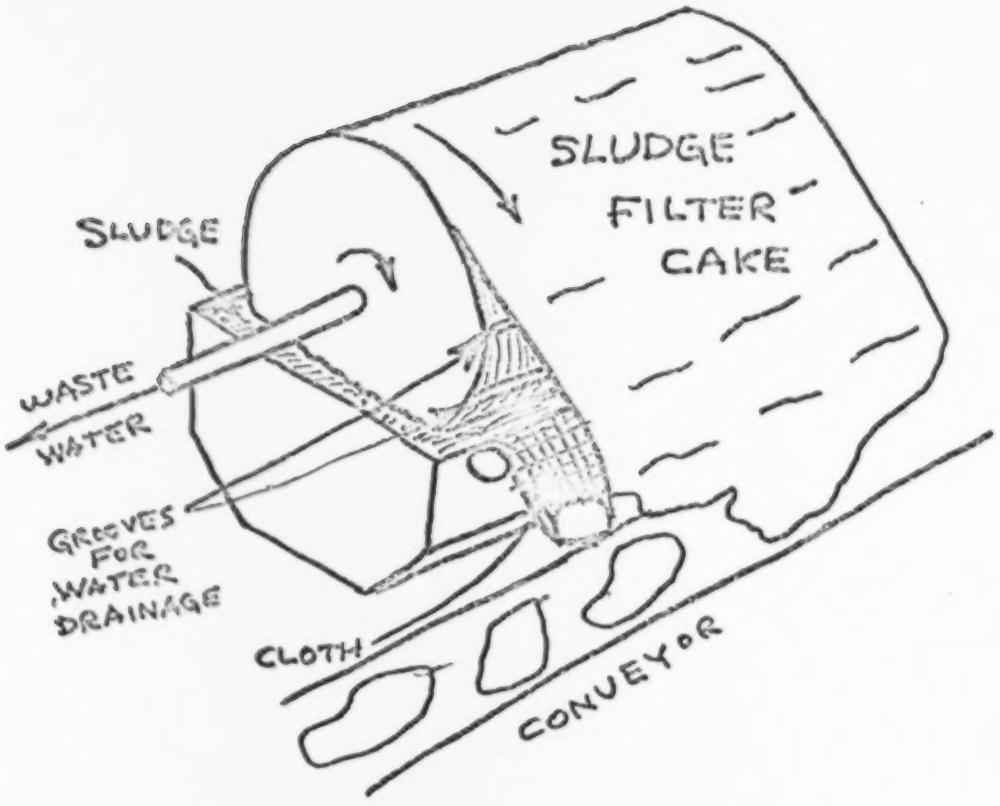
c. A vacuum drier is faster than a sand bed.



Here, the wet sludge is carried up over a rotating drum covered with a cloth or with wire coils. There is a vacuum (☐ behind / ☐ outside) of the drum covering.

behind

c. A vacuum drier is faster than a sand bed.



Here, the wet sludge is carried up over a rotating drum covered with a cloth or with wire coils. There is a vacuum (☐ behind / ☐ outside) of the drum covering.

behind

water

d. In vacuum drying, the _____ is drawn off through grooves across the face of the drum.

sludge, or cake

e. At a point where most of the water has been removed, the covering is pulled away and run over a roller, forcing the dried _____ to drop off.

conveyer

f. The dried sludge is carried away on a _____, for final disposal.

4.19 Digested sludge which has been dewatered or dried is used for land fill or for soil conditioner.

organic

a. Sometimes the sludge is incinerated before or after dewatering, to complete the destruction of the _____ material in it.

can

b. Sludge which has been digested and dried or incinerated (☐ still cannot / ☐ can) be disposed of <u>without</u> creating foul odors and attracting rats.

14.10 The liquid (<u>supernatant liquor</u>) from the digester is still loaded with organic material.

influent

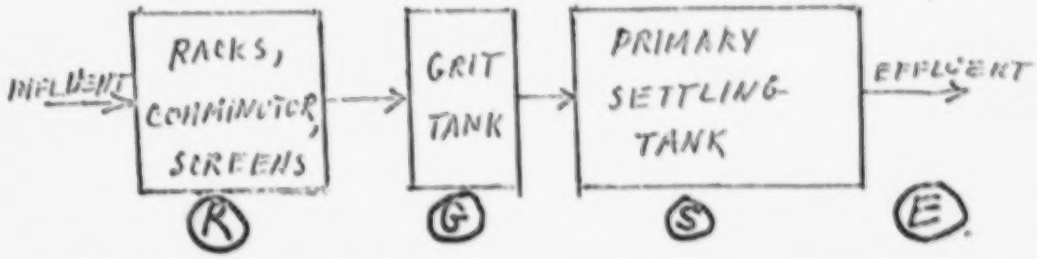
a. The supernatant liquor is returned to the plant (☐ influent / ☐ effluent).

14.11 The combination of screening, settling and sludge disposal processes is called primary treatment. A treatment plant that uses only these primary processes is a primary treatment plant.

a. The effluent from a primary treatment plant may contain pollutants which are dissolved or are too fine to be _____.

settleable, or settled

b. Here is a sketch showing part of a primary treatment system:



In this system, there is a _____ tank between the racks and the settling tank.

grit

c. The grit tank removes the (□ largest / □ smallest) particles of sand and grit.

largest

d. By using the letters R, G, S and E (for Racks, Grit tank, Settling tank and Effluent) show where each of the following would turn up in the treatment system. (Some would be found in more than one place).

R	Rags_____
R	Sticks_____
G, S	Sand_____
S, E	Suspended organic material_____
R, G	Gravel_____
(S), E	Dissolved Material_____
R, G	Metal_____

SELF TEST VI

racks, screens

1. In primary treatment, large solid objects are removed by _____ or _____, or they may be _____ by comminutors.

ground, or pulverized

protect

2. The large solids are removed at the entrance to the system, to _____ the pumps.

slowly

3. Settleable suspended solids are removed by allowing the wastewater to flow (rapidly / slowly) through a settling tank.

larger
high

4. Solid particles settle better when they are (larger / smaller) and have a (high / low) specific gravity.

flocculate or clump

5. Chemicals are sometimes added to _____ fine particles, so that they settle in the settling tanks.

a small part
sticks, or clings

6. The settling solids remove (most / a small part) of the dissolved material, because it _____ to them.

bacteria or microorganisms

7. Part of the organic material is destroyed by _____ during the settling process.

effluent

8. Some fine and dissolved pollutants remain in the _____ that flows out of the primary treatment system.

organic

9. The raw sludge taken from the settling tanks must be treated further, to destroy the _____ material it contains.

digesters

anaerobic

10. The most common method of treatment of raw sludge is carried out in tanks called _____, where the sludge is acted upon by _____ bacteria.

water

dewatered, or dried

11. Digested sludge contains too much _____ for easy handling, so it is _____ before final disposal.

influent

12. The supernatant liquor from the digester goes into the plant (☐ influent / ☐ effluent).

fuel

13. The gas from the digester may be used as _____.

THOUGHT QUESTIONS

1. Some types of clay soils easily form particles finer than baby powder. If a primary treatment plant receives much clay of this type, what can be done to help remove it, without changing the size of the settling tanks?

2. Many cities have laws against connecting rainspouts to sanitary sewers. This keeps large overloads of water from a heavy rain from causing problems in the wastewater treatment plant. Among other things, the rapid flow of water from such an overload may decrease the effectiveness of the settling tanks. WHY?

3. Soap and other detergents suspend dirt in water, so that it is easier to remove during cleansing processes. These suspensions usually make up a portion of the wastewater of a community. What are the main effects of detergents in primary treatment plants?

The answers to these questions are on the next page.

Answers to Thought Questions

1. Flocculating chemicals may be used.

2. Eddies and turbulence keep the particles suspended, and the increased velocity may carry them on through the tank before they can settle out.

3. They cause foaming and interfere with the settling operations, and may be toxic to microorganisms responsible for wastewater treatment. (They also contain enough phosphorus to increase plant life in the receiving water.)

SECONDARY TREATMENT

15. The effluent from a primary treatment plant may contain enough fine and dissolved pollutants to make its quality unsatisfactory. In this case, secondary treatment is needed. In secondary treatment systems, conditions are adjusted to favor biodegradation of the pollutants. The most common secondary treatment processes are the trickling filter process and the activated sludge process.

15.1 Both the trickling filter process and the activated sludge process allow aerobic microorganisms to act on the wastewater.

a. Both of the common secondary treatment processes are carried out in (☐ open / ☐ closed) systems.

open

b. Artificial heating (☐ is / ☐ is not) used in these biological treatment processes.

is not

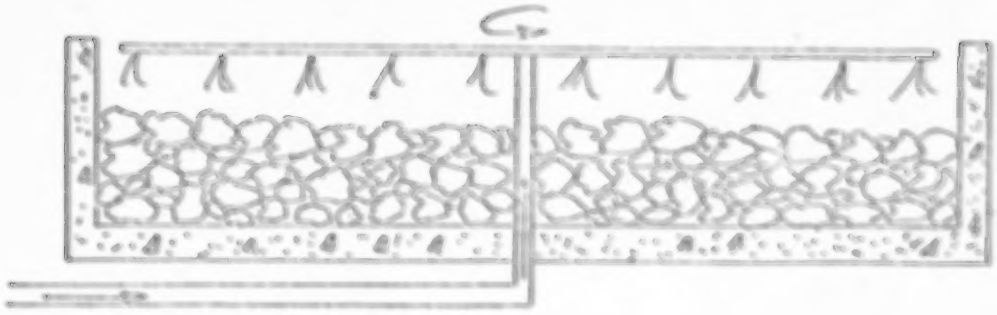
c. For the aerobic microorganisms to convert organic material effectively, they have to have a good supply of _____.

oxygen or air

d. To keep the microorganisms healthy and growing, some microorganisms are (☐ added / ☐ removed) as the treatment goes on.

removed

15.2 Here is a sketch of a "trickling filter."



In this system, the wastewater from a primary settling system is sprayed from a rotating pipe to moisten a bed of rocks or other solid material. Microorganisms form a slime on the surface of the solids.

a. The bed must be made of large pieces, with enough space between them so that the aerobic microorganisms at the bottom can get the _____ they need.

air, or oxygen

b. With such large spaces, the "trickling filter" has (☐ a very good / ☐ almost no) filtering effect.

almost no

c. The effect of the "trickling filter" comes almost entirely from the _____ in the bed.

microorganisms or slime

d. If the bed becomes plugged up, the spaces may fill with water, and the _____ supply is cut off.

air

fill, or block

e. As the microorganisms grow, they tend to _____ the spaces between the rocks.

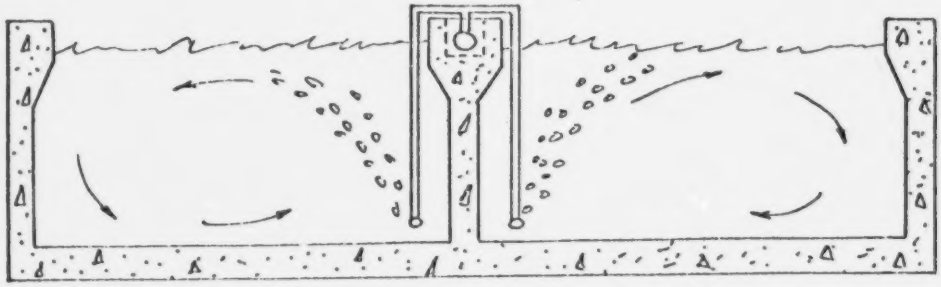
slime, or microorganisms

f. When the bed is operating properly, the movement of the water washes some of the _____ _____ off the rocks, keeping the spaces open.

removes

g. The microorganisms in the bed remain in the growth phase, because as the slime "sloughs off" it _____ some microorganisms.

15.3 Here is a sketch of part of an activated sludge system:



In this system, air is bubbled through the wastewater, keeping it stirred up. The microorganisms float around in slimy clumps of "activated sludge."

a. The little bubbles shown in the sketch are bubbles of _____.

air

b. The air supplies the _____ that the microorganisms need.

oxygen

c. The microorganisms can use the oxygen only after it has _____ in the wastewater.

dissolved

d. The oxygen dissolves best when the air bubbles are (☐ large / ☐ small) and when the wastewater mixing is (☐ good / ☐ poor).

small

good

e. Dissolved and fine suspended material from the wastewater tends to _____ on the surface of the slimy clumps of sludge.

stick, or cling

growth

f. The microorganisms are most effective if they are kept in their _____ phase all the time.

removed

g. To keep the microorganisms growing vigorously, some of the sludge has to be _____ to prevent over-crowding.

organic

h. Removal of sludge is called "wasting". The amount of sludge that should be wasted depends upon the total amount of _____ material in the wastewater.

interfere with

i. The air bubbles (☐ help / ☐ interfere with) settling of the sludge for removal.

sludge, or microorganisms

j. The wastewater leaving the mixing tank carries some of the _____ along with it.

15.4 Sludge "sloughs off" of the rocks in a trickling filter. Sludge is carried along in the wastewater leaving the mixing tank of an activated sludge system. This sludge must be removed before the wastewater is discharged.

settle

a. The suspended sludge is removed in a separate tank, where low velocity allows it to _____.

more
less

b. The sludge from this secondary settling tank contains (☐more / ☐fewer) microorganisms and (☐more / ☐less) inorganic material than primary sludge does.

requires

c. Secondary sludge (☐requires / ☐does not require) digestion before final disposal.

dewatered or dried

d. Just like primary sludge, the secondary sludge is _____ after digestion, to decrease its volume.

15.5 Whether wastewater goes through primary treatment alone, or also goes through secondary treatment, it is often chlorinated before it is discharged into the receiving water.

microorganisms or germs

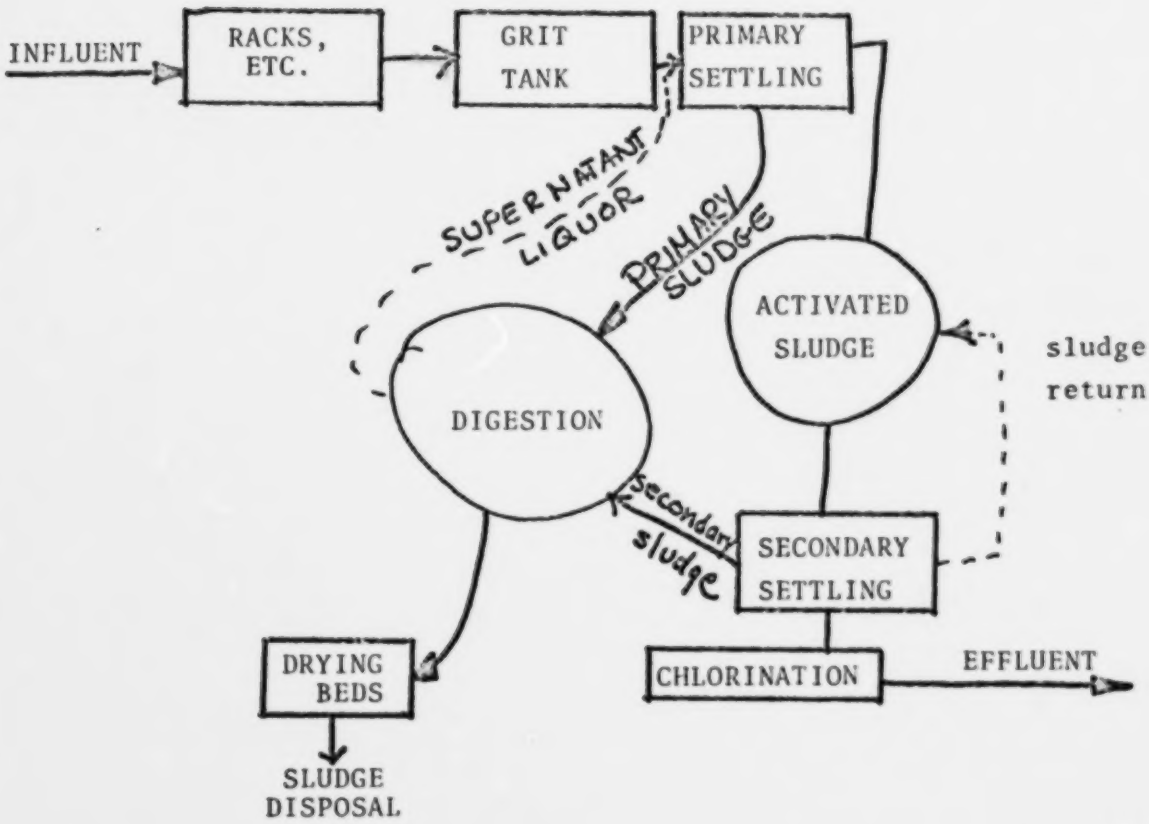
a. Chlorination makes certain that no live _____ are discharged into the receiving water.

sick

b. Chlorination is insurance that the effluent from the treatment plant cannot make people _____.

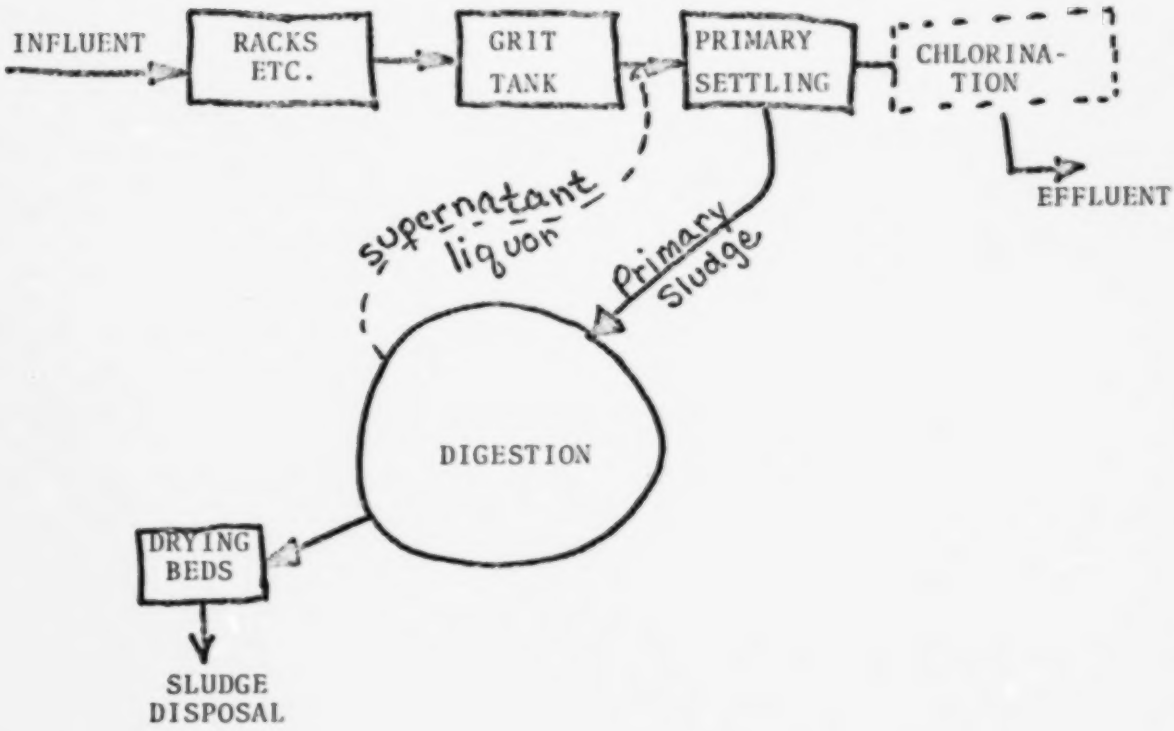
15.6 A secondary treatment plant contains all of the settling and digestion processes of a primary treatment system, plus a biological secondary treatment process.

a. Here is a sketch of a secondary wastewater treatment plant.



Draw a circle around the part of the plant that would be called a primary treatment plant, and show where the effluent would be taken off from such a plant.

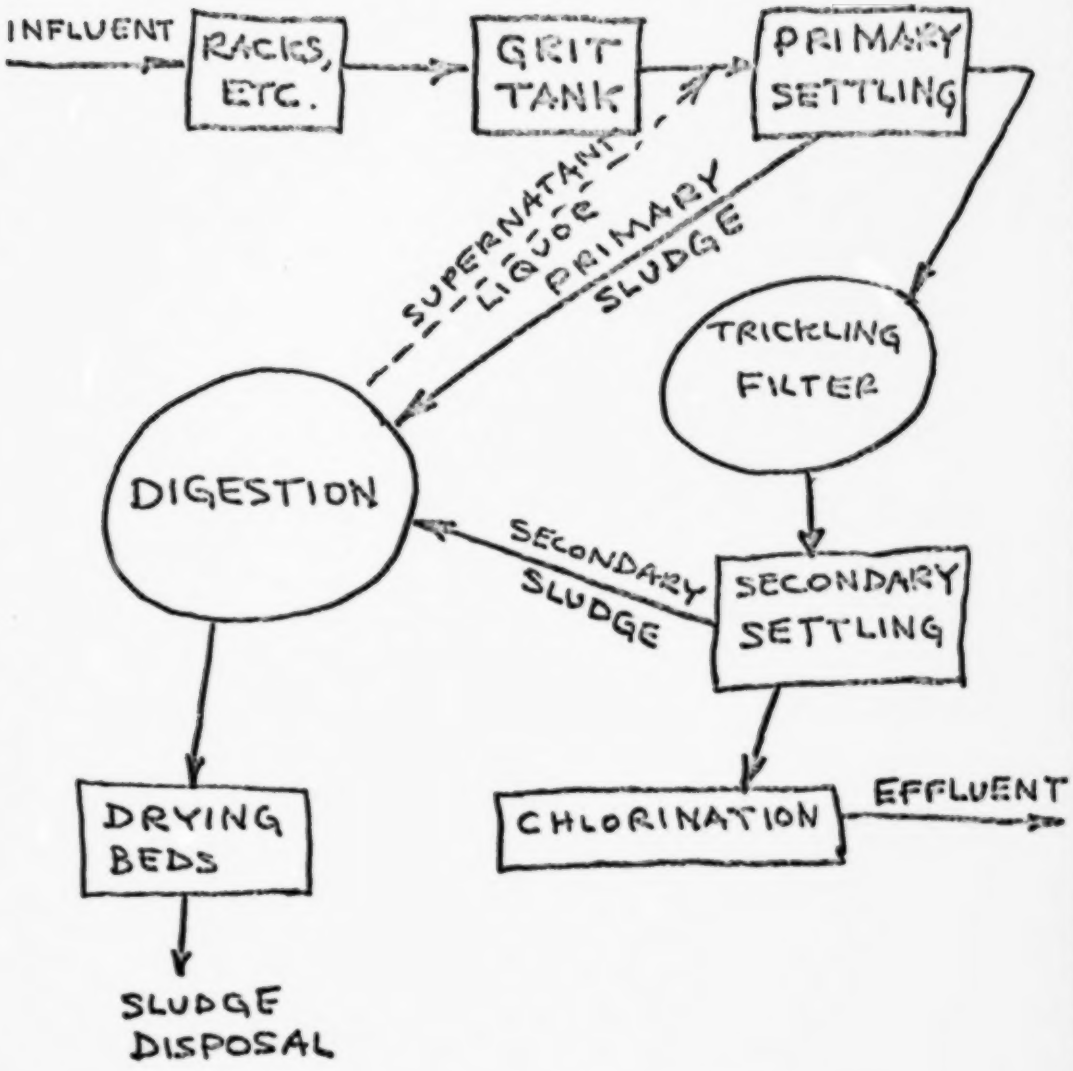
b. Here is the part of the plant you should have circled on the previous page:



Now connect in the additional equipment that would be needed to convert this primary treatment plant to a secondary treatment plant using a trickling filter.

The correct answer is on the next page.

c. Here is a complete trickling filter plant:



The supernatant liquor from the digester can be returned directly to the primary settling tank, because it contains no _____ or _____.

There are many possible answers, such as: sand, grit, branches, metal, rags...

SELF TEST VII

1. Secondary treatment is necessary when the effluent from a primary treatment plant contains too high a concentration of _____.

pollutants, or organics

2. The most common secondary treatment processes are the _____ _____ process and the _____ _____ process.

activated sludge

trickling filter

3. Both secondary biological treatment processes use (☐aerobic /☐anaerobic) microorganisms.

aerobic

4. Both secondary biological treatment processes need a supply of dissolved _____.

oxygen

5. In the trickling filter, air reaches the microorganisms through the large spaces between the _____.

rocks

6. In the activated sludge system, oxygen is dissolved out of the _____ of air forced into the wastewater.

bubbles

rocks

7. In a trickling filter, the microorganisms are in the slime that clings to the _____.

sludge, or slime

8. In the activated sludge process, the suspended clumps of _____ contain the microorganisms.

has to

9. Secondary sludge (☐ has to / ☐ does not have to) be digested and dewatered before disposal.

removal

10. "Wasting" is the _____ of sludge.

chlorine

11. To prevent the spread of disease, the effluent from either a primary or secondary treatment plant may be treated with _____.

THOUGHT QUESTIONS

1. An accident in a chemical plant causes a large quantity of germicide to be discharged down the sewer. Shortly afterward, the level of organic pollutants increases in the effluent from the wastewater treatment plant. WHY?

2. A great deal of effort is being made to force detergent manufacturers to make their products more biodegradable. Why does increased biodegradability make them less troublesome?

The answers to these questions appear on the next page.

Answers to Thought Questions.

1. The germicide killed the microorganisms in the secondary treatment section of the plant.

2. The biodegradable detergents are broken down before they interfere with settling operations in the treatment plant.

APPENDIX A

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Revised 3-15-68

WHAT IS PROGRAMMED LEARNING?

1. A programmed learning booklet helps you to learn better and faster than an ordinary book, because you can check how well you are doing, as you go.

1.1 The program is made up of a series of steps, or frames.

a. If a frame contains a blank space, you write in it the single _____ that best completes the frame, and then you look here to _____ your work.

word

check

b. The program should give you enough information to fill in the blank without _____ at the printed word at the left.

looking

c. You may not see the reason behind each particular frame, but if you follow all the steps carefully, the frames will help you to _____ the subject.

learn, or understand

1.2 To get the best results from this program, you should use a piece of cardboard or heavy paper as a mask.

cover, or mask — a. Get one now, and use it to _____ the printed words at the left until after you have

filled — _____ the blanks.

b. You should slide the mask down just far

written — enough to check yourself after you have _____ a word in each blank in the frame.

1.3 You should be sure you understand each step before you go on.

a. Always check yourself, but only after you have

frame, or step — filled in all the blanks in one _____.

b. If you can't decide what word fits in a blank, the frames you have finished may have clues that

help — will _____ you to find the word.

c. If you have trouble with a frame, you

should — (☐ should / ☐ must not) go back and look at the frames you have already finished.

d. If your word doesn't match the one at the left, you may still be correct, if your word has the same

meaning — general _____ as the printed one.

1.4 Sometimes a frame asks you something that "everybody" knows.

a. A frame like this is just to remind you of something that you will _____ in later frames.

need, or use

1.5 Some frames just ask you to choose the best word or phrase from a set, for example:

a. Fluoride is used in water supplies to
(☐ kill rats /☐ reduce tooth decay /☐ find leaks).

reduce tooth decay

1.6 A frame may give you a piece of information, then check immediately to see if you understood it.

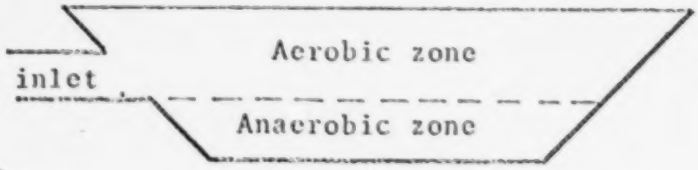
Here's an example:

Gravity is often used to move water through treatment plants.

a. In such a plant, the water inlet has to be
(☐ higher /☐ lower) than the water outlet.

higher

1.7 A frame may ask you to get information from a drawing:



Waste stabilization lagoon

a. The upper zone in this waste stabilization lagoon is the _____ zone.

aerobic

1.8 Good programs are designed to let you pace yourself, with little or no direction from a teacher.

a. A good program (☐ can / ☐ cannot) be used at home.

can

b. The speed of completing a program should be set by the (☐ author / ☐ teacher / ☐ student).

student

1.9 A program is <u>not</u> a test.

a. A test tries to find out what you know, but a program tries to _____ you something new.

teach

b. After you complete a program, you may be tested to see what you have _____, but the program itself is never used as a _____.

learned

test

c. The main purpose of a program is to _____ you, step by step, at a speed set by _____.

teach

yourself, or you

On the next page, there is a test, to let you see what you have learned from this program.

TEST YOURSELF

1. A program is:

   a. a test b. a method of learning

2. The speed of completing a program is set by:

   a. the student b. the teacher

   c. the author of the program

3. The small steps that make up a program are called _____.

4. To get the best results from a program you should use a piece of cardboard or heavy paper to _____ the _____.

5. If you can't decide how to complete a frame, the first thing you should do is:

   a. take a wild guess b. look under the mask

   c. look for clues in the frames you have already finished.

6. When you have completed a frame you should immediately _____ the mask and _____ your answers, to be sure you _____ the material before you go on.

The answers to this test are given on the next page.

1. b

2. a

3. frames

4. cover, or mask
   answers

5. c

6. move, or slide
   check
   understand, or know